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Converting Chlorohydrocarbon Wastes by Chlorolysis

Repro Chemical Corp, Washington, D C

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CONTROLLING CONTAMINATION FROM WASTES OF CHLORIDES

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16. ABSTRACT The report gives results of an assessment of the magnitude of the waste chlorohydrocarbon problem in the U.S., and a study of the applicability of the conversion of this waste by chlorolysis as a means of resolving the problem. An estimated 86,400 metric tons per year of chlorohydrocarbon waste is generated in the U.S. A portion of this waste is treated by chlorolysis to solvents, and by incineration. The balance is disposed of by deep well injection or burial. The identified waste is a suitable feedstock for a chlorolysis operation if it is pretreated to remove particulate materials and moisture. Geographically, the waste is generated primarily along the Gulf Coast, from Corpus Christi to New Orleans. The Gulf Coast concentration indicates that a regional waste disposal facility (including a chlorolysis unit, a waste pretreatment unit, and a conventional incineration unit) would be viable. Preparation of a design and firm capital estimate is recommended as the next step in an overall program leading to such a regional facility.

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Conclusions

1. There are about 190MM lb/year (86,400 metric tons) of chlorohydrocarbon wastes generated in the U.S. by vinyl chloride monomer and chlorinated solvents producers that would be suitable chlorolysis feedstocks.
2. The distribution of these wastes is about 80 per cent from vinyl chloride monomer production and 20 per cent from solvents production.
3. The wastes are produced primarily in Gulf Coast locations where the critical raw material hydrocarbons and chlorine are readily available.
4. The pesticide manufacturers do not produce wastes that are suitable chlorolysis feedstocks.
5. The supply of chlorine over the next five years will be adequate to meet the needs of a chlorolysis plant to process 25,000 U.S. tons/year (22,700 metric tons) of waste.
6. The 91,000 U.S. tons (82,700 metric tons) of carbon tetrachloride produced by a chlorolysis plant can be assimilated by the market provided the fluorocarbon market continues to grow.

7. A regional waste disposal unit which embodies a chlorolysis unit and is capable of processing other wastes should be constructed in a Gulf Coast location.

8. A regional waste disposal facility is estimated to cost about $40MM and would have a 5-14 per cent return on the investment at capacity.

Recommendations

1. Preparation of a design and capital estimate is recommended to establish a more quantitative basis for proceeding with the implementation of a regional waste disposal unit.
2. The base case feedstock recommended for design of the chlorolysis plant is 60 per cent VCM wastes mixed with 40 per cent solvent wastes.
3. Examination of the sensitivity of the plant capacity to feedstock variations is recommended. The range to be examined is from 100 per cent VCM waste to about 20 per cent VCM mixed with 80 per cent solvents waste.
4. Consideration of the Bay St. Louis, Mississippi NASA facility as a location for the regional waste disposal unit is recommended.
5. Evaluation of the viability of other potential feedstocks is recommended.

Introduction

The disposal of wastes generated in the manufacture of chlorohydrocarbons such as vinyl chloride, perchloroethylene, trichloroethylene and various pesticides has become a significant problem in the United States. In 1972,[1] an estimated 350,000 tons per year of hard-to-treat residue were generated during the production of almost 10 million tons per year of chlorinated hydrocarbons. Methods of disposing of these wastes range from ocean discharge, burial, and deep well injection to open-pit burning and enclosed incineration. Use of the non-destructive methods results in undesirable environmental exposures. Similarly, use of the destructive methods, although more acceptable environmentally, is wasteful of critical raw material resources.

Conservation of these resources by conversion to industrially useful materials in an environmentally acceptable manner is very desirable. A proprietary process[2,3] offers the potential of fulfilling both of these requirements. This process is capable of converting chlorohydrocarbon wastes to carbon tetrachloride by exhaustive chlorination.

The assessment of the magnitude of the waste chlorohydrocarbon problem in the US and the applicability of this new technology as a means of resolving the problem was undertaken on behalf of the USEPA. Inherent in this assessment was a detailed definition of the waste problem, potential economics, impact of this new technology in the carbon tetrachloride market, and the availability of chlorine.

This report summarizes the results of the assessment program sponsored by the USEPA under contract number 68-03-0456.

Magnitude of the U.S. Chlorohydrocarbon Waste Problem

A survey of current chlorohydrocarbon and pesticide producers was conducted to ascertain the present magnitude of the waste problem. The results of this survey, summarized in Table I, show that the waste chlorohydrocarbons come from two major industries, vinyl chloride monomer, and chlorinated solvents. The reports received from these industries indicate that the volume of waste generated annually averages about 190MM pounds (86,360 metric tons) and is made up of 150MM pounds (68,200 metric tons) of VCM waste and 40MM pounds (18,200 metric tons) of solvent waste.

The wastes are produced in EPA regions IV, VI, and VII. The majority of the waste, 106 out of the total 190MM lbs. is produced in EPA Region VI which is the Gulf Coast area. This high concentration of waste producers which ranges from Corpus Christi, Texas to New Orleans, Louisiana indicates that a central disposal facility located in this highly industrialized region could prove viable.

The wastes are characterized to a degree by their producing processes. The vinyl chloride wastes have the unique characteristic of containing hydrogen in the molecule whereas the solvent wastes do not contain hydrogen. This comes about through the higher degree of chlorination and higher temperatures required to make chlorinated solvents. Typical analyses of the waste fractions from both vinyl chloride and chlorinated solvents operations are presented in Table IA. The components in these wastes range from C_1 through C_6 chlorohydrocarbons and chlorocarbons. They are all suitable feeds for a chlorolysis process. By the same token, the fractions containing C_1, C_2, and C_3 chlorohydrocarbons are suitable feeds for a conventional chlorinolysis process as is discussed later in this report. However, the prime concern is how much of these materials are or could be made available for chlorolysis.

The majority of the waste producers are still dependent upon contract services for the disposal of their wastes. Fees for a typical incineration service range from $120-150 per U.S. ton of waste processed. This fee is expected to continue to rise in

concert with labor and raw material rates. Hence, it is believed that a lower cost service, such as is possible with chlorolysis, could attract a substantial portion of the waste chlorohydrocarbons now being incinerated. An estimated 65MM lbs/year of vinyl chloride wastes and 40MM lbs/year of chlorinated solvent wastes are projected to be convertible to the use of chlorolysis if the contract service is provided at a cost of $100 per U.S. Ton. However, the total 105MM lb/yr. of waste would produce about 180-190MM lb/yr. of carbon tetrachloride. This volume of product represents about 34 per cent of the total market for carbon tetrachloride and as such could not be readily accommodated. A more realistic volume to consider is not to exceed 20 per cent of the market. This would limit the initial chlorolysis plant capacity to the processing of 50MM lbs/yr. (25,000 U.S. tons/yr.) of wastes.

The normal feed for this unit should be a mixture of 60 per cent by weight vinyl chloride waste and 40 per cent by weight solvent wastes.

Magnitude of the U.S. Pesticide Waste Problem

The results of the survey also revealed that the pesticide industry does not produce significant quantities of waste suitable for chlorolysis. This finding is particularly significant because more than 200 pesticides are produced in the United States. However, an analysis of these pesticides was made to ascertain why this should be the case. This analysis showed that of the 209 pesticides identified in Tables II through IV, forty (40) contain sulfur, thirty two (32) contained a combination of sulfur and phosphorus, eleven (11) contain only phosphorus, seventy three (73) contain nitrogen, forty (40) contain oxygen and only thirteen (13) contain the most desirable elements carbon hydrogen and chlorine. These thirteen compounds are:

Aldrin
Chlordane
DD
DDT
Ethylene dichloride
Benzene hexachloride
Heptachlor
Lindane
o-Dichlorobenzene
p-Dichlorobenzene
Pentac
Perthane
TCBC

Of these compounds, Aldrin, chlordane, and DDT are the largest volume pesticides but each has been banned by the USEPA for environmental reasons. Ethylene dichloride, although used as a pesticide, is manufactured primarily as an intermediate enroute to polyvinyl chloride polymer and could be processed to useful product by this route.

The other compounds, DD, benzene hexachloride, heptachlor, lindane, dichlorobenzene, Pentac, Perthane, and TCBC are products manufactured in too low a volume, mostly less than 1MM lb/year[5] (~450 metric tons), to be of great significance as a source of waste chlorohydrocarbons.

The elements contained in the balance of the pesticides (196) make them questionable candidates for chlorolysis but will be considered in the section of this report dealing with the criteria for acceptability as chlorolysis feedstocks.

The survey also revealed that no private firm had retained any stocks of banned pesticides but that government agencies had significant stocks. The list of materials and amounts of each type of formulation are summarized in Table VII.[6]

Criteria for Acceptability as Chlorolysis Feedstock

Theoretical consideration of the criteria indicates that almost any chlorinated hydrocarbon would make a suitable feed. However, the presence of elements other than carbon, hydrogen and chlorine in a compound give rise to significant questions regarding product handling and corrosion. Furthermore, the presence of particulate materials such as inorganic catalyst particles and/or free carbon could pose a significant mechanical problem in the operation and maintenance of critical control equipment.

The chlorolysis process[4] has been used successfully to process chlorohydrocarbons. It has also been shown to have potential for processing oxygenated chlorohydrocarbons. Carbonyl chloride is coproduced with the carbon tetrachloride when oxygenated chlorohydrocarbons are processed.

However, the presence of small amounts of sulfur have been shown to be extremely corrosive to the nickel tube used for constructing the reactor. The sulfur content of the feed must be kept below 25 ppm to be acceptable.

This criterion can probably be met by diluting the sulfur containing feed with other feeds. This method of dealing with the sulfur problem is projected to limit the rate at which sulfur containing feeds could be processed and the volume of storage required for inventory.

The effect of nitrogen and/or phosphorus when combined in the feed materials is unknown. The most critical aspects of these elements are that nitrogen trichloride is explosive and phosphorus trichloride is pyrophoric. Neither of these compounds is desirable for the aforementioned reasons. Their presence would seriously complicate the operation of a chlorolysis plant.

The presence of particulate materials in the feed, particularly inorganics and free carbon present problems in that they could be expected to accumulate in the system and also interfere with the operation of the critical pressure control valves required to maintain the operating pressure at 120 atmospheres. For these reasons, the feed to the reactor must be cleaned. Filtration or distillation are considered as preferred pretreatment methods. These provisions will be dealt with in another section of this report.

In summary, acceptable feeds for chlorolysis must be free of particulates, must not contain sulfur in excess of 25 ppm and must not contain nitrogen or phosphorus. They may, however, contain some oxygen.

Pretreatment of Chlorolysis Feedstock

Pretreatment of the wastes and banned pesticides appears to be essential for effective operation of a chlorolysis plant. The presence of particulate material in the waste chlorohydrocarbons offers the potential of plugging or jamming the critical pressure control devices of a chlorolysis plant. These particulates are fine carbon particles generated in typical ethylene dichloride pyrolysis operations and catalyst fragments carried through in fluidized bed type chlorinators. The carbon particles appear to be too fine to remove by conventional filtration. Consequently, an evaporation or distillation method appears most suitable. A sophisticated fractional distillation does not appear to be an essential ingredient of this process.

Pretreatment of banned formulated pesticides is quite complex because of the large number of formulations possible. The wettable powder type of formulation can be processed by first extracting the active ingredients from the support using a suitable solvent. Several useful solvents and the qualitative solubilities of various pesticides in these solvents has been included as Table VIII.

Xylene, benzene, methylene chloride, and carbon tetrachloride would be the most compatible solvents for use with the chlorolysis process. Carbon tetrachloride would be most desirable because it would be routinely available. The use of other solvents may prove to be necessary on a selected basis.

Filtration is the preferred method for separating the inert carriers from the extract. This technique represents the least energy intensive mode of operation with the best reliability. Concentration of the extract may or may not be necessary.

In summary, the installation of a pretreatment system which embodies the capability of both filtration and evaporation or distillation is considered an essential adjunct to a chlorolysis plant.

Chlorine Availability

A list of chlorine producers[7] is presented in Table IX. The total installed capacity in 1973 was 31,480 tons per day (28,620 metric tons). Several major expansions have been announced with some of these plants now on-stream. The total announced capacity is 10,765 tons per day (~9800 metric tons) to be in place by 1980. The majority of these expansions are to be located in the Gulf Coast region of the United States where the prime users are located.

The timing of these expansions appears to be satisfactory for coping with projected growth rates in the consuming industries. However, major dislocation of supply could occur if the energy situation again becomes critical. Optimistically, this is not expected to occur. Conversion of power generating facilities on the Gulf Coast from critical natural gas users to oil and/or coal users could be expected to alleviate a possible chlorine shortage resulting from a short supply of natural gas.

The volume of chlorine required to operate a chlorolysis unit converting 25,000 tons per year (22,700 metric tons) of typical vinyl chloride monomer waste is 300 tons per day (273 metric tons). This volume represents about 3 per cent of the announced plant expansions. Thus, it would appear that the chlorine requirements of a chlorolysis plant could be readily accommodated by the chlorine industry within the next five years.

Alternate Methods of Treating Chlorohydrocarbon Wastes

Incineration is relied upon as the most effective method now practiced in the United States for the disposal of chlorohydrocarbon wastes. Two approaches, conventional thermal incineration and catalytic incineration have been developed. Catalytic incineration as represented by the B. F. Goodrich "Catoxid" process is the most recent addition.[8] This technology is based upon the operation of a fluid bed reactor with hydrogen chloride, water and carbon dioxide as products. It appears to be suitable for operation in conjunction with large vinyl chloride plants which can readily accept the hydrogen chloride without purification.

An apparently attractive alternate to incineration is chlorination to perchloroethylene, trichloroethylene and carbon tetrachloride. The patent literature indicates that Dow, Diamond Alkali and Pittsburgh Plate Glass have developed processes suitable for the conversion of C_1 through C_3 hydrocarbons to chlorinated solvents.

The Dow Chemical process as revealed in U. S. patent number 2,422,324 claims the ability to convert C_1, C_2, and C_3 hydrocarbons and their partially chlorinated derivatives to a mixed product of perchloroethylene and carbon tetrachloride. The patent further claims a yield of 94-95% of desirable products with the balance being hexachlorobenzene. The operating temperature of the process is about 600°C. Unfortunately, the hexachlorobenzene is one of the hard to treat wastes typical of solvent processes.

The Diamond Alkali process as described in British Patent No. 673,565 claims the ability to convert ethylene dichloride to perchloroethylene and trichloroethylene. This process operates at a temperature of about 400°C using Fuller's earth as catalyst in a fluid bed. The combined yield of perchloroethylene and trichloroethylene is about 90 per cent. The balance of the product is undefined but is estimated to contain such materials as hexachloroethane, hexachlorobutadiene, hexachlorobenzene, tetrachloroethane and pentachloroethane. These latter two compounds may be recycled and pyrolyzed to trichloroethylene and

perchloroethylene. The operating temperature when compared against that of the Dow process does not appear to be adequate to convert C_3 chlorohydrocarbons to useful products. Thus, the hexachlorobutadiene and hexachlorobenzene would be residues from this process.

However, the process does have merit as a means of processing vinyl chloride wastes to useful products because the chlorination of ethylene dichloride to both trichloroethylene and perchloroethylene must proceed through the intermediate C_2 chlorohydrocarbons.

The Pittsburgh Plate Glass process is described in several patents issued in Britain, France, and the United States. U.S. Patent Nos. 3,267,162 and 3,288,868 disclose the use of a fluid bed catalytic oxychlorination process for the conversion of ethylene dichloride and other C_2 chlorohydrocarbons to trichloroethylene and perchloroethylene. This process is operated at a temperature of about 400°C. The trade literature indicates that the yield of products is about 85%. The balance probably goes to carbon oxides and waste chlorocarbons such as hexachlorobutadiene and hexachlorobenzene.

The process also appears to offer the possibility of processing vinyl chloride wastes to useful products.

The results of the industry survey show that at least two and probably three companies are processing their vinyl chloride monomer wastes by chlorination to solvents. This appears logical in that three of the major vinyl chloride producers are also solvent producers.

However, there is a total of 50-60MM lbs/yr. (23,000-27,000 metric tons) of vinyl chloride waste that could be made available for chlorolysis that are currently projected for incineration at sea.

In summary, it is possible to process a portion of the vinyl chloride monomer wastes by presently known technologies. However, each of these technologies produces residues more difficult to process. These residues must be processed either by chlorolysis or incineration.

Impact of Chlorolysis on the Carbon Tetrachloride Market

The total industry capacity for carbon tetrachloride is estimated to be about 540,000 U.S. tons per year (~491,000 metric tons). However, this capacity is flexible because perchloroethylene and carbon tetrachloride are coproducts. The ratio of these products can be varied to satisfy swings in the marketplace. The known producers and their estimated capacities are shown in Table X.

About 80 per cent of the carbon tetrachloride produced is used in the manufacture of Freon-11 and 12 for refrigeration and propellant usage. The balance of 20 per cent is used for miscellaneous applications and export.

Growth of the carbon tetrachloride market has been closely related to the growth of the fluorocarbon market. The growth of this market through 1975 has been about 6 per cent per year. The fastest growth has been experienced by the propellant application. This represents some 40 per cent of the fluorocarbon market.

However, the recent concern about the depletion of the ozone layer attributed to the C_1 fluorocarbons is projected to slow the

growth of the propellant market. This slow down is expected to continue until the ozone depletion question is resolved.

Introduction of additional carbon tetrachloride capacity during this period looks at first glance to be undesirable. However, it could be accomplished with the proper pricing strategy.

A chlorolysis unit rated at 25,000 U.S. tons/year of residues would produce about 92,000 U.S. tons (83,640 metric tons) of carbon tetrachloride. This represents 17 per cent of the current industry capacity. This influx of new capacity could have significant effect upon the producers which still use the carbon bisulfide route for manufacture.

However the future of the carbon tetrachloride market is undefinable until the ozone depletion situation is resolved.

Impact of Chlorolysis on the Carbonyl Chloride Market

The total industry capacity for carbonyl chloride is estimated to be about 620,000 U.S. tons per year (~565,000 metric tons). The known producers and their estimated capacities are shown in Table XI. Most of this capacity is used captively for the manufacture of isocyanates, carbamates and polycarbonates. The major consumer is the isocyanate industry which is projected to grow at the rate of 10-21 per cent per year. Expansions in carbonyl chloride capacity will be made consistent with the growth in isocyanate capacity.

Hence, by 1980 the additional carbonyl chloride capacity required is estimated to be 500MM lbs/yr. (~230,000 metric tons).

It is estimated that a chlorolysis unit to process 25,000 tons/yr. of residue could produce a maximum of about 15,000 U.S. tons (~13,600 metric tons) of carbonyl chloride. This volume of material could be readily absorbed into the isocyanate market.

However, the chlorohydrocarbon wastes identified in this study do not contain oxygen and would not yield carbonyl chloride.

Injection of oxygen into the reactor would be necessary to induce the formation of carbonyl chloride. This technique must be explored experimentally to verify that it can be used.

Impact of Chlorolysis on the Hydrogen Chloride Market

The total industry capacity for 100 per cent hydrochloric acid is about 2.0MM U.S. tons per year (~1.8MM metric tons). About 85 per cent of this capacity is by-product from other processes. Less than half of the capacity is used in definable markets. The balance is either used in oxyhydrochlorination processes or it is neutralized.

Thus, the introduction of new hydrochloric acid capacity could not be effected economically. A chlorolysis unit processing 25,000 tons per year (~22,700 metric tons) of vinyl chloride residues would produce a maximum of about 30,500 U.S. tons of hydrochloric acid (~27,700 metric tons). Effective utilization of this hydrochloric acid within the confines of a chlorolysis plant is very desirable. The options available for this need include oxyhydrochlorination of ethylene to make saleable ethylene dichloride or conversion back to chlorine by either the Kel Chlor process or the Uhde electrolysis process.

Facilities to accomplish this objective should be estimated as part of the chlorolysis plant.

Recommendations for Chlorolysis

A. Plant capacity and process variations

The waste chlorohydrocarbon supply indicates that a plant with a capacity to process 25,000 U.S. tons/year of waste would be viable. This capacity should be adequate to serve the needs of the industry when allowance is made for incineration facilities that are projected to come on stream in the time period required to construct a chlorolysis plant.

The reactor in this plant should be of a segmented design with two to three spare sections provided for flexibility in use and to permit change out of corroded sections.

A base case design for the plant should be made with a feed that is a mixture containing 60 per cent by weight VCM wastes and 40 per cent by weight chlorinated solvents wastes. The effect of variations in feedstock composition upon reactor capacity should also be examined.

Suggested cases for examination are:

1. 100 per cent vinyl chloride wastes.

2. Solvent wastes with minimum vinyl chloride wastes.

The second case is proposed to evaluate the limiting composition that can be fed to the reactor and still have a self-sustaining reaction.

Preparation of a design and provision of space in the plant layout for the future installation of a carbonyl chloride recovery and packaging system is recommended.

Consideration of providing facilities for converting the by-product hydrochloric acid to a useful product is also recommended. Evaluation of the economic merits of the following options should be made:

(i) Oxyhydrochlorination of ethylene
(ii) Electrolysis of muriatic acid
(iii) Conversion to chlorine via the Kel Chlor process
(iv) Production of anhydrous HCl
(v) Neutralization
(vi) Production of muriatic acid

B. Pretreatment/Purification Needs

Pretreatment of all wastes will be necessary. A combination system providing filtration and distillation capability is recommended. This system must contain an autoclave for use in extracting pesticides from their inert carriers.

Purification of the carbon tetrachloride to meet the specifications for fluorocarbon use is recommended because this is the market in which the product will most likely move. Purification of carbonyl chloride will be necessary to make it acceptable for use in isocyanate processes. Removal of chlorine, hydrogen chloride, and carbon tetrachloride to less than 1.0 weight per cent is recommended.

C. Site Locations

The majority of the chlorohydrocarbon wastes and chlorine producers are located in the Gulf Coast area ranging from Corpus Christi, Texas to New Orleans, Louisiana.

The major concentration is from Houston, Texas to New Orleans.

Location of a chlorolysis plant anywhere in the area between Houston and New Orleans would be suitable. The location must be accessible by both water and rail transport. The Bay St. Louis, Mississippi area which offers these characteristics is recommended for consideration. However, an economic study is recommended to establish the best compromise on freight rates.

D. Mode of Implementation

A chlorolysis unit should best be implemented with a dual parallel reactor system such that at least one reactor can be in operation at all times. This mode of implementation is recommended because future wastes as yet undefined could result in serious corrosion problems and/or require frequent shutdowns.

Installation of the carbonyl chloride recovery and packaging system should be deferred until it can be

appropriately scheduled to coincide with a significant growth in the isocyanate area. The capacity of this system should not exceed 15,000 U.S. tons/year (13,600 metric tons).

A thermal incinerator capable of processing wastes that are not acceptable for chlorolysis is recommended for inclusion in the system. This should be capable of incinerating the carbonaceous material recovered from the pretreatment step of the chlorolysis unit.

E. Relative Cost Advantages

A chlorolysis plant designed for a capacity of 25,000 U.S. tons/year (22,700 metric tons) would produce 92,000 U.S. tons/year (83,600 metric tons) of carbon tetrachloride and 30,500 U.S. tons/year (27,700 metric tons) of hydrogen chloride. The sale of carbon tetrachloride at $320-400 per U.S. ton would produce a gross sales income of $29.5-36.8MM per year. The administrative, sales, and general expenses for large volume contractual sales is estimated to be about 10 per cent.

The manufacturing cost was estimated as follows:

Raw Materials	
Wastes @ $100 per ton	$(2,500,000)
Chlorine @ $150 per ton 97,500 tons	14,640,000
Miscellaneous	1,000,000
Total	$13,140,000
Cost of Conversion	8,750,000
Total production cost	$21,890,000

On this basis, the gross profit before tax would be in the range of $4.5-11MM for capacity operation.

The investment projected for the chlorolysis plant is estimated to be about $20MM for the primary facilities. The auxiliary facilities for use of the hydrogen chloride, pretreatment and incineration facilities are estimated to add an additional $20MM for a total of $40MM. The return on this investment at capacity operation is estimated to be in the range of 5-14 per cent.

The magnitude of the return on investment projected for the established solvents processes is about 10 per cent. Thus, the chlorolysis process appears to be competitive with established technology.

Incineration on the other hand is a losing proposition when no effort is made to recover chlorine. Typically, shipboard incineration of 13,000 tons/year (11,800 metric tons) of vinyl chloride wastes would cost about $1.6MM at a processing cost of $120 per U.S. ton.

In summary, a large scale regional chlorolysis plant provides the potential for economics competitive with existing solvents processes.

Bibliography

1. Hot Option for Disposal of Hydrocarbon Wastes
   Chemical Week, April 19, 1972, page 37.

2. Process for the Manufacture of Carbon Tetrachloride
   Krekeler et.al., U.S. Patent NO. 3,651,157 March 21, 1972.

3. Process for the Manufacture of Carbon Tetrachloride
   Krekeler et.al., U.S. Patent NO. 3,676,508 July 11, 1972.

4. The High Pressure Chlorolysis of Hydrocarbons to Carbon Tetrachloride--A New Process for the Utilization of Chlorinated Hydrocarbon Wastes.
   Krekeler, Schmitz, and Rebhan, Hoechst, A.G.
   Presented at the National Conference on the Management and Disposal of Residues, February 3-5, 1975, Washington, D.C.

5. Synthetic Organic Chemicals, Pesticides, and Related Products, United States Tariff Commission Report 1974.

6. World Wide Pesticide Inventory, Solid Waste Management Division, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Maryland.

7. Chemical Marketing Reporter, August 5, 1976.

8. Energy Conservation in The Chemical Industry Through New Process Development--The B. F. Goodrich Catoxid Process.
   Fabstein and Elder, Presented at the Federal Energy Administration, Project Independence Hearing, San Francisco, California, October 7, 1974.

Table 1

Chlorohydrocarbon Wastes

VCM Producers

EPA Region	Waste Volume MM lb/yr	Composition		Current Treatment
VI	9.0	$CH_{1.9}Cl_{1.1}$	(lights)	
	7.0	$CH_{1.4}Cl_{1.2}$	(heavies)	Incineration/ Chlorinolysis
	11.0	$CH_{1.5}Cl_{0.8}$	(heavies)	Incineration
	27.0			
VI	6.0	$CH_{1.9}Cl_{1.1}$	(lights)	----
VI	10.0	$CH_{2.1}Cl_{0.9}$	(lights)	Chlorinolysis
	5.0	$CH_{1.5}Cl_{1.5}$	(heavies)	Incineration/ Chlorinolysis
	10.0	$CH_{1.4}Cl_{0.8}$	(heavies)	Incineration
	25.0			
VI	18.0	----	(heavies)	Incineration
VI	10.6		(lights)	Used in another process
	19.3		(heavies)	Partial recovery/ incineration
	29.9			
VII	12.0	$CH_{1.6}Cl_{0.7}$	(heavies)	Chlorinolysis
VII	9.0	$CH_{I.5}Cl_{0.8}$	(heavies)	Chlorinolysis
IV	25.0	$CH_{1.6}Cl_{0.7}$	(heavies)	Incineration
TOTAL	151.5 MM lb/yr	$CH_{1.6}Cl_{0.7}$	(heavies)	Incineration

Table I (Cont'd)

Chlorohydrocarbon Wastes

Solvent Producers

EPA Region	Waste Volume MM lb/yr	Composition	Current Treatment
IV	0.48	$C_6H_6Cl_6$	Landfill
VI	10.0	C_4Cl_6	Incineration
VI	20.0	C_4Cl_6	Deep Well
VI	3.0	C_4Cl_6	Incineration
VI	10.0	C_4Cl_6	Burial
	43.0		

Table IA

COMPOSITION OF VCM & SOLVENT WASTES

	VCM		SOLVENTS
Component	Lights % by wt.	Heavies % by wt.	% by wt.
$CHCl_3$	9.92	-----	-----
CCl_4	16.85	0.7	-----
C_2H_5Cl	3.76	-----	-----
$C_2H_4Cl_2$	30.2	2.2	-----
$C_2H_3Cl_3$	-----	48.5	-----
C_2H_3Cl	10.85	-----	-----
$C_2H_2Cl_2$	4.45	0.5	-----
C_2HCl_3	2.86	-----	-----
$C_2H_2Cl_4$	-----	2.3	-----
C_2Cl_6	-----	-----	25.
$C_3H_3Cl_3$	-----	0.7	-----
$C_3H_4Cl_2$	-----	2.7	-----
$C_3H_6Cl_2$	-----	1.7	-----
C_4H_5Cl	14.5	2.7	-----
$C_4H_6Cl_2$	-----	26.0	-----
C_4Cl_6	-----	-----	65.0
C_6H_6	6.21	-----	-----
C_6Cl_6	-----	-----	10.0
$C_6H_{6-x}Cl_x$	-----	3.9	-----
Unknowns	0.4	8.1	-----
Total	100.0	100.0	100.0

Table II

SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
	Antu	Penick	B,CO	$C_{11}H_{10}N_2S$ (solid)
Asulam	Asulox	May and Baker	L,CO	$C_8H_{10}N_2O_4S$ (solid)
Diallate	Avadex	Monsanto	EC,G	$C_9H_{17}OSCl_2N$ (liquid)
Triallate	Avadex BW Far Go	Monsanto	EC,G	$C_9H_{16}OSCl_3N$ (liquid)
Captan	Orthocide	Stauffer Chevron	D,WP	$C_9H_6O_2SCl_3N$ (solid)
	Dexon	Chemagro	G,WP	$C_8H_{10}N_3SO_3Na$ (solid)
Captafol	Difolatan	Chevron	D,T,F	$C_{10}H_7O_2Cl_4NS$ (solid)
Endosulfan	Thiodan	FMC	D,EC,T,WP,G,CO	$C_8H_4Cl_6O_3S$ (solid)
	Eptam	Stauffer	EC,G	$C_9H_{19}NOS$ (liquid)
	Ethion	FMC	D,EC,G,T,WP	$C_9H_{22}O_4P_2S_4$ (liquid)
Ametryne	Evik Gesapex	Geigy	WP	$C_8H_{13}N_5S$ (solid)
Ferbam		FMC Pennwalt	WP	$C_9H_{18}N_3S_6Fe$ (powder)
Folpet	Phaltan	Chevron Stauffer	D,WP	$C_9H_4O_2NSCl_3$ (solid)

Table II (Cont'd)

SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
	Lethan 384	Rohm and Haas	CO,PC	$C_9H_{17}O_2NS$ (oil)
Maneb	Manzate Tersan LSR Dithane M-22	DuPont Rohm and Haas Pennwalt	WP	$[C_4H_6N_2S_4]_xMny$ (solid)
Thiabendazole	Mertect	Merck	WP,F	$C_{10}H_7N_3S$ (solid)
Methomyl	Lannate	DuPont	SP	$C_5H_{10}O_2N_2S$ (solid)
MCA600	Mobam	Mobil	G,WP	$C_{10}H_7O_2NS$ (solid)
	Morestan	Chemagro	WP	$C_{10}H_6ON_2S_2$ (solid)
Nabam	Dithane D-14 Dithane A-40	Rohm and Haas FMC	D,CO,WP	$C_4H_6N_2S_4Na_2$ (solid)
	Niacide	FMC	D,WP	(solid)
DO-14	Omite	Uniroyal	D,EC,WP	$C_{19}H_{26}O_4S$ (liquid)
Molinate	Ordram	Stauffer	EC,FM,G	$C_9H_{17}ONS$ (liquid)
Phenothiozine		West	T,WP	$C_{12}H_9NS$ (solid)
Nitralin	Planavin	Shell	L,WP	$C_{13}H_{19}O_6N_3S$ (solid)
Oxycarboxin	Plantvax	Uniroyal	L,WP	$C_{12}H_{13}O_4NS$ (solid)

Table II (Cont'd)

SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Prometryne	Caparol Gesagard	Geigy	WP	$C_{10}H_{19}N_5S$ (solid)
Cycloate	Ro-Neet	Stauffer	EC,G	$C_{11}H_{21}ONS$ (liquid)
Butylate	Sutan	Stauffer	EC,G	$C_{11}H_{23}ONS$ (liquid)
Tetrachlorothiophene	Phenphene	Pennwalt	EC	C_4Cl_4S (solid)
Aldicarb	Temik	Carbide	G	$C_7H_{14}O_2N_2S$ (solid)
Terbutryn	Igran 80W GS14260	Geigy	WP	$C_{10}H_{19}N_5S$ (solid)
	Terrazole	Olin	EC,G.L,S,T,WP	$C_5H_5N_2Cl_3S$ (liquid)
Tetradifon	Tedion	FMC Thomas Hayward	D,EC,WP	$C_{12}H_6O_2Cl_4S$ (solid)
	Thanite	Hercules	T	$C_{12}H_{15}O_2NS$ (liquid)
Thiram	Arasam Thylate Tersan	DuPont	D,WP	$C_6H_{12}N_2S_4$ (solid)
Pebulate	Tillam	Stauffer	EC,G	$C_{10}H_{21}ONS$ (liquid)
Metham-Sodium	Vapam	Stauffer	S	$C_2H_8NS_2O_2Na$ (solid)
	Vegadex	Monsanto	EC,G	$C_8H_{14}NClS_2$ (liquid)

Table II (Cont'd)

SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Vernolate	Vernam	Stauffer	EC,G	$C_{10}H_{21}ONS$ (liquid)
Zinck		FMC Rohm and Haas Stauffer	D,WP	$[C_4H_6N_2S_4]_xZny$ (solid)

Table III

PHOSPHOROUS AND SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
	Abate	Cyanamid	EC,G	$C_{16}H_{20}P_2O_6S_3$ (liquid)
	Akton	Shell	EC	$C_{12}H_{14}O_3PSCl_3$ (liquid)
	Aspon	Stauffer	EC,G,FM	$C_{12}H_{28}O_5P_2S_2$ (liquid)
	Betason Prefar	Stauffer	EC,FM,G	$C_{14}H_{24}O_4NPS_3$ (liquid)
Fensulfathion	Dasanit	Chemagro	EC,L,T	$C_{11}H_{17}O_4PS_2$ (liquid)
	Def	Chemagro	EC	C H P O S* (liquid)
Diazinon	Sarolex Alfatox Basudin	Geigy	D,EC,G,PC,S,WP	$C_{12}H_{21}N_2O_3PS$ (liquid)
Dimethoate	Cygon Rogor	Cyanamid Montedison Sumitomo	EC,WP	$C_5H_{12}O_3NPS_2$ (solid)
Dioxathion	Delnav	Hercules	EC	$C_{12}H_{26}O_6P_2S_4$ (liquid)
Disulfoton	Disyston	Chemagro	FM,G.L,T	$C_8H_{18}O_2PS_2$ (liquid)
Chlopyrifos Dowco 179	Dursban	Dow	EC,G,T,WP	$C_9H_{11}O_3Cl_3NPS$ (solid)
	Dyfonate	Stauffer	G,EC	$C_{10}H_{15}OPS_2$ (liquid)
	EPN	DuPont	EC,WP,G,T	$C_{14}H_{14}NO_4PS$ (solid)

Table III (Cont'd)

PHOSPHOROUS AND SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Fenthion	Baytex Entex	Chemagro	EC,G,T	$C_{10}H_{15}O_3PS$ (liquid)
	Folex Mexphas	Mobil	EC	$C_{12}H_{27}PS_3$ (liquid)
	Gophacide	Chemagro	T,B	$C_{14}H_{13}O_2Cl_2N_2PS$ (solid)
Azenphosmethyl	Guthion	Chemagro	EC,WP,L	$C_{12}H_{16}O_3N_3PS_2$ (solid)
	Imidan	Stauffer	EC,WP	$C_{11}H_{12}O_4NPS_2$ (solid)
Malathion	Cythion	Cyanamid	T,CO,EC,WP,D	$C_{10}H_{19}O_6PS_2$ (liquid)
Demeton-O-Methyl Sulfoxide	Meta-SystoxR	Chemagro	EC,L,T	$C_6H_{15}O_4PS_2$ (liquid)
Methyl Parathion	Metron Methyl Niran Folidol M Metacide Nitrox	Monsanto Stauffer Kerr McGee	EC,WP,S	$C_8H_{10}O_5NPS$
Prophos	Mocap	Mobil	EC,G	$C_8H_{19}O_2PS_2$ (liquid)
Ortho 9006 Methamidophos	Monitor Tamaron	Chevron Chemagro	L,T	$C_2H_8O_2NPS$ (solid)
Acephate	Orthene	Chevron	G,PC	$C_4H_{10}O_3NPS$ (solid)
Parathion		Monsanto Stauffer Kerr McGee	D,EC,G,L,WP	$C_{10}H_{14}O_5NPS$ (liquid)

Table III (Cont'd)

PHOSPHOROUS AND SULFUR CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Phorate	Thiamet	Cyanamid		$C_7H_{17}O_2PS_3$ (liquid)
Ronnel	Korlan Trolene Nankor	Dow	EC,G,L,PC,S	$C_8H_8O_3Cl_3PS$ (solid)
Methidiathon	Supracide	Geigy	EC	$C_6H_{11}O_4N_2PS_3$ (solid)
Demeton	Systox	Chemagro	EC,L	$C_8H_{19}O_3PS_2$ (liquid)
Carbophenothion	Trithion	Stauffer	EC,WP,G	$C_{11}H_{16}O_2ClPS_3$ (liquid)
Dichlorofenthion	VC-13	Mobil	EC	$C_{10}H_{13}O_3Cl_2PS$ (liquid)
Thionazin	Zinophos	Cyanamid	EC,G	$C_8H_{13}O_3N_2PS$ (liquid)

Table IV

PHOSPHOROUS CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Monocrotophos	Azodrin	Shell	L	$C_7H_{14}O_5PN$ (liquid)
Dicrotophos	Bidrin	Shell	L	$C_8H_{15}O_5PN$ (liquid)
	Ciodrin	Shell	D,EC	$C_{14}H_{19}O_6P$ (liquid)
Dichlorvas	Vapona	Shell	EC,G,L,S,T	$C_4H_7O_4PCl_2$ (liquid)
Trichlorfon	Dylox Dipterex	Chemagro	G,L,S,SP	$C_4H_8O_4PCl_3$ (solid)
	Gardona Rabon	Shell	D,S.WP	$C_{10}H_9O_2PCl_4$ (solid)
Mevinphos	Phosdrin	Shell	EC,L,S,T	$C_7H_{13}O_6P$ (liquid)
Naled	Dibron	Chevron	EC,L,T	$C_4H_7O_4Cl_2Br_2P$ (solid)
	Phosfon	Mobil	D,L	$C_{19}H_{32}Cl_3P$ (solid)
Phosphamidon	Dimecron	Chevron	D,L,S,T	$C_{10}H_{19}O_5NPCl$ (liquid)
	Ruclene	Dow	EC,CO	$C_{12}H_{22}O_3NClP$ (solid)

Table V

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Atrazine	Aatrex Gesaprim	Geigy	WP, L	$C_8H_{14}N_5Cl$ (solid)
Chloramben	Amiben	Amchem	G,L,S	$C_7H_5O_2Cl_2$ (solid)
Terbutol	Azak	Hercules	G,WP	$C_{17}H_{27}NO_2$ (solid)
Barban	Carbyne	Gulf	EC	$C_{11}H_9NO_2Cl_2$ (liquid)
Propoxur	Baygon	Chemagro	D,EC,G,L,PC, T,WP	$C_{11}H_{15}O_3N$ (solid)
Chlonitrolid	Bayluscide	Chemagro	WP,G	$C_{15}H_{15}O_5N_3Cl_2$ (solid)
Benomyl	Benlate Tersan 1991	DuPont	WP	$C_{13}H_{18}N_4O_3$ (solid)
Phenmedipham	Betanal	Nor.Am.	EC	$C_{16}H_{16}N_2O_4$ (solid)
Binapacryl	Morocide	FMC Hoechst	D,WP	$C_{15}H_{17}O_6N_2$ (solid)
	Bladex	Shell	G,WP	$C_9H_{13}N_6Cl$ (solid)
Bromacil	Hyvar X Hyvar X-L Hyvar X-P Krovar I Krovar II	DuPont	WP,S,P	$C_9H_{12}O_2N_2Br$ (solid)

Table V (Cont'd)

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Bromoxynil	Brominal	Amchem	EC	$C_7H_3NBr_2O$ (solid)
Bromoxynil Octanoate	Buctril	Chipman	EC	$C_{15}H_{17}NBr_2O_2$ (liquid)
Metalkamate	Bux Ten	Chevron	EC,G,T	$C_{13}H_{19}O_2N$ (solid)
Carbaryl	Sevin	Carbide	D,FM,G,L,P,T, WP	$C_{12}H_{11}O_2N$ (solid)
Carbofuran	Furadan	FMC	G,F	$C_{12}H_{14}O_3N$ (solid)
Formetanate	Carzol	Nor.Am.	SP	$C_{11}H_{15}O_2N_3$ (solid)
Propham	Chem Hoe	PPG	EC,G,F	$C_{10}H_{13}O_2N$ (solid)
Chlorbromuron	Maloran	Geigy	G,WP	$C_9H_{10}O_2N_2ClBr$ (solid)
Chlordimeform	Fundal Galecron	Nor.Am. Geigy	D,EC,SP	$C_{10}H_{13}N_2Cl$ (solid)
Chloropicrin	Chlor-O-Pic Picfume	Great Lakes Niklor Dow	L,PC	CCl_3NO_2 (liquid)
Chloroxucon	Tenoran	Geigy	WP	$C_{15}H_{15}O_2N_2Cl$ (solid)
Chlorpropham	Chloro IPC CIPC	PPG	EC,G	$C_{10}H_{12}O_2NCl$ (solid)

Table V (Cont'd)

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Dinitramine	Cobex	U.S. Borax	EC	$C_{11}H_{13}O_4N_4F_3$ (solid)
Cycloheximide	Acti Dione	TUCO	WP	$C_{15}H_{15}O_4N$ (solid)
	Cycocel	Cyanamid	L	$C_5H_{13}NCl_2$ (solid)
Dodine	Cyprex Melprex	Cyanamid	WP	$C_{15}H_3O_2N_3$ (solid)
Chlorothalonil	Daconil 2787 Bravo	Diamond Shamrock	C,WP,F	$C_8Cl_4N_2$ (solid)
DCNA	Botran	TUCO	D,WP	$C_6H_3N_2O_2Cl_2$ (solid)
Deet	Det Diethyltoluamide Metadelphene	MGK Chem Form Hercules	PC,S,L	$C_{12}H_{17}ON$ (liquid)
Dichlobenil	Casoron	Thompson Hayward	G,WP	$C_7H_3NCl_2$ (solid)
Dinoseb	Sinox Sinox General Basanite Caldox Gebutor Subitex	Dow BASF Hoechst	EC,S	$C_{10}H_{12}O_5N_2$ (liquid)
Diphenamid	Dymid Enide	Elanco TUCO	L,WP,G	$C_{16}H_{17}ON$ (solid)
Diphenylamine		Cyanamide	WP	$C_{12}H_{11}N$ (solid)

Table V (Cont'd)

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Diuron	Kamex Karmex DL Krovar I Krovar II	DuPont	WP,F	$C_9H_{10}ON_2Cl_2$ (solid)
	Dyrene	Chemagro	G,WP	$C_9H_5N_4Cl_3$ (solid)
Fluometuron	Cotoran	Geigy	WP	$C_{10}H_{11}ON_2F_3$ (solid)
Fluorodifen		Geigy	EC,G,WP	$C_{13}H_7N_2O_5F_3$ (solid)
Norea	Herban	Hercules	WP	$C_{13}H_{20}ON_2$ (solid)
Isopropalin	Paarlan	Elanco	EC	$C_{15}H_{23}O_4N_3$ (liquid)
	Karathane Dinocap Arathane Mildex	Rohm & Haas	WP,G,C	$C_{18}H_{24}O_6N_2$ (liquid)
Alachlor	Lasso	Monsanto	EC,G	$C_{14}H_{20}O_2NCl$ (liquid)
Linuron	Lorox Afalon	DuPont Hoechst	G,WP	$C_9H_{10}O_2N_2Cl_2$ (solid)
Maleic Hydrazido	MH-30 Sucker Stuff	Chem.Form Ansul Uniroyal	L,S	$C_4H_4O_2N_2$ (solid)
Metrobromuron		Geigy	G,WP	$C_9H_{11}O_3N_2Br$ (solid)

Table V (Cont'd)

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
	MGK 264	MGK	T,PC,S	$C_{17}H_{23}O_2N$ (solid)
	MGK 326	MGK	T,S,PC	$C_{13}H_{17}O_4N$ (liquid)
Monuron	Telvar	DuPont	WP,F	$C_9H_{11}ON_2Cl$ (solid)
Monuron TCA	Urox	Allied	EC,G,L	$C_{11}H_{12}O_3N_2Cl_4$ (solid)
Neburon	Kloben	DuPont	WP	$C_{12}H_{16}ON_2Cl_2$ (solid)
Tetramethrin	Neo Pynamin	FMC	EC,PC,S,T,D	$C_{19}H_{22}O_4N$ (solid)
	Nicotine	Chem. Form.	L	$C_{10}H_{14}N_2$ (liquid)
Nitrofen	TOK	Rohm & Haas	EC,WP	$C_{12}H_7O_3NCl_2$ (solid)
Cyprazine	Outfox	Gulf	EC	$C_9H_{14}N_5Cl$ (liquid)
Paraquat	Gramoxone	Chevron	L	$C_{12}H_{14}N_2^{+2}$ (solid)
Parinol	Parnon	Elanco	EC	$C_{18}H_{13}ONCl_2$ (solid)
PCNB	Terraclor Brassicol	Olin Hoechst	C,D,EC,FM,G,L,WP	$C_6Cl_5NO_2$ (solid)

Table V (Cont'd)

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Picloram	Tordon	Dow	CO	$C_6H_3O_2N_2Cl_3$ (solid)
Piperalin	Pipron	Elanco	EC	$C_{16}H_{21}O_2NCl_2$ (liquid)
	Princep	Geigy	SP	$C_7H_{12}N_5Cl$ (solid)
Propanil	Rogue Stam F-34	Monsanto Rohm & Haas	EC	$C_9H_8ONCl_2$ (solid)
Propazine	Milogard Gesamil	Geigy	WP	$C_9H_{16}N_5Cl$ (solid)
Pyrazon	Pyramin	BASF	WP	$C_{10}H_8ON_3Cl$ (solid)
Propachlor	Ramrod	Monsanto	G,WP	$C_{11}H_{14}ONCl$ (solid)
	Randox	Monsanto	EC,G	$C_8H_{12}ONCl$ (liquid)
SADH	Alar 85	Uniroyal	C,L,SP	$C_6H_{12}O_3N_2$ (solid)
Siduron	Tupersan	DuPont	WP	$C_{14}H_{20}ON_2$ (solid)
Ethoxyquin	Stop Scald	Monsanto	EC	$C_{14}H_{18}ON$ (liquid)
Karbutilate	Tandex	FMC	G,WP	$C_{14}H_{21}O_3N_3$ (solid)

Table V (Cont'd)

NITROGEN CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
2,3,6-TBA	Trysben	DuPont	L,S	$C_9H_{10}O_2NCl_3$ (solid)
Terbacil	Sinbar	DuPont	WP	$C_9H_{13}O_2N_2Cl$ (solid)
	Urab	Allied	EC,L,P	$C_{11}H_{13}O_3N_2Cl_3$ (solid)
Carboxin	Vitavax	Uniroyal	G,WP	$C_{12}H_{13}O_3N$ (solid)
Dowco 139	Zectran	Dow	EC,S,WP	$C_{12}H_{18}O_2N_2$ (solid)

Table VI

OXYGEN AND CHLORINE CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Chloropropylate	Acaralate	Geigy	EC	$C_{17}H_{16}O_3Cl_2$ (solid)
	Aldrin	Shell	G,S,L	$C_{12}H_6Cl_4$ (solid)
Allethrin	Pynamin	Sumitomo	...,PC	$C_{19}H_{26}O_3$ (liquid)
Banvel	Dicamba	Velsicol	G,S	$C_8H_6O_3Cl_2$ (solid)
Chlordane	Chlordane	Velsicol	D,EC,G,WP	$C_{11}H_4Cl_8$ (liquid)
Chlorobenzilate	Acaraben	Geigy	EC	$C_{16}H_{14}O_3Cl_2$ (liquid)
Chloroneb	Demosan 65W Tersan SP	DuPont	WP	$C_8H_8O_2Cl_2$ (solid)
2,4-D	2,4,D	Thompson Hayward Dow Chipman Diamond	EC,G,L,T	$C_8H_6O_3Cl_2$ (solid)
DACTHAL	DACTHAL	Diamond	G,WP	$C_{10}H_6O_4Cl_4$ (solid)
DALAPON	Basfapon Dowpon	BASF Dow	SP,C	$C_3H_4O_2Cl_2$ (solid)
2,4-DB	Butoxone	Chipman	CO,EC,L,S	$C_{10}H_{10}O_3Cl_2$ (solid)

Table VI (Cont'd)

OXYGEN AND CHLORINE CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
DD	Vidden D Telone & Telone C	Shell Dow	L	$C_3H_4Cl_2$ & $C_3H_6Cl_2$ (liquid)
DDT	DDT	Montrose	EC,L,T,WP	$C_{14}H_9Cl_5$ (solid)
Dichlone	Phygon	FMC	D,WP	$C_{10}H_3O_2Cl_2$ (solid)
Dichlorprop		Diamond	EC	$C_9H_8O_3Cl_2$ (solid)
Dicofol	Kelthane	Rohm & Haas	EC,WP	$C_{14}H_9OCl_5$ (solid)
Dieldrin		Shell	D,EC,G,WP	(solid)
Dimethrin		MGK	EC,T	$C_{19}H_{26}O_2$ (liquid)
Diphacin	Diphacinone	Velsicol	D,CO	$C_{23}H_{15}O_3$ (solid)
D-trans Allethrin	Bioallethrin	MGK	T,S,PC	$C_{19}H_{27}O_3$ (liquid)
Endothall	Aquathol	Pennwalt	CO,G	$C_8H_4O_5$ (solid)
Endrin		Shell Velsicol	D,EC,G,WP	(solid)
Entocon ZR-512		Zoecon	EC,G	$C_{17}H_{30}O_2$ (liquid)

Table VI (Cont'd)

OXYGEN AND CHLORINE CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Entocon ZR-515		Zoecon	EC,G	$C_{18}H_{32}O_3$ (liquid)
Erbon	Baron	Dow	EC	$C_{11}H_9O_3Cl_5$ (solid)
Ethylene Dichloride		Diamond	L	$C_2H_4Cl_2$ (liquid)
Ethylhexanediol	Rutgers 612	Carbide	L	$C_8H_{18}O_2$ (liquid)
Fortified Hexachloride	BHC	Hooker	T	$C_6H_6Cl_6$ (solid)
Glytac	EGT	Oxychem	L,S	$C_4H_4O_4Cl_6$ (solid)
Heptachlor		Velsicol	D,EC,G	$C_{10}H_4Cl_7$ (solid)
Indalone	Butopyronoxyl	FMC	L	$C_{11}H_{17}O_4$ (liquid)
Kepone		Allied	D,W,B	(solid)
Lindane	Y-BHC (90%)	Hooker	C,T	$C_6H_6Cl_6$ (solid)
MCPA	Rhomene Chiptox Rhonox	Chipman Diamond	EC	$C_9H_9O_3Cl$ (solid)
MCPB	Thistrol Cen-Trol	Amchem Chipman	EC,L,S,CO	$C_{11}H_{13}O_3Cl$ (solid)

Table VI (Cont'd)

OXYGEN AND CHLORINE CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
MCPP	ViPar	Vineland	S,EC,T	$C_{10}H_{11}O_3Cl$ (solid)
Methoxychlor	Marlate Moxie	DuPont Ansul Chem. Form.	D,EC,G WP,T	$C_{16}H_{15}O_2Cl_3$ (solid)
Mirex		Hooker	B	(solid)
Orthodichlorobenzene	1,2 DCB.	Monsanto Hooker	L,PC	$C_2H_4Cl_2$ (liquid)
Orthophenylphenol	Dowicide 1	Dow	Flakes	$C_{12}H_5O$ (solid)
Paradichlorobenzene	Santochlor PDB	Monsanto PPG Allied	C	$C_6H_4Cl_2$ (solid)
PCP	Santobrite	Monsanto Dow Vulcan	P,S,EC,WP	C_6HOCl_5 (solid)
Pentac		Hooker	WP	$C_{10}Cl_{10}$ (solid)
Perthane		Rohm & Haas	EC,WP,D	$C_{18}H_{20}Cl_2$ (solid)
Piperonyl butoxide	Butacide	FMC MGK	D,WP,T,S PC	$C_{18}H_{30}O_5$ (liquid)
Protect		Gulf	D	$C_{12}H_5O_3$ (solid)

Table VI (Cont'd)

OXYGEN AND CHLORINE CONTAINING PESTICIDES

NAME	TRADE NAME	MFG.	PRODUCT FORM.	TECHNICAL FORMULA
Pyrethrins	Pyrethrum	FMC MGK Prentiss Penick	D,EC,L,CO PC	(varied) (liquid)
Resmethrin	Nia 17370 Chryson SBP 1382	FMC Sumitomo Penick	PC	$C_{22}H_{25}O_3$ (solid)
Rotenone		Prentiss Penick FMC	D,L,WP	$C_{23}H_{19}O_6$ (solid)
Silvex		Thompson Hayward Dow	EC	$C_9H_7O_3Cl_3$ (solid)
2,4,5-T	Ded-Weed	Thompson Hayward Diamond Dow	EC	$C_8H_5O_3Cl_3$ (solid)
TCBC		Monsanto	G	$C_7H_4Cl_4$ (liquid)
Toxaphene		Hercules	D,EC,G,WP	$C_9H_{10}Cl_8$ (solid)
Warfarin	Coumafene Dethmor	Penick Prentiss	D,CO	$C_{19}H_{16}O_4$ (solid)

Table VII

U.S. ARMY PESTICIDES SUITABLE FOR CHLOROLYSIS WITH PRETREATMENT

Pesticide	Concentration & Form	Quantity	
		U.S. Tons	Metric Tons
DDT	100% powder	2.47	2.25
	75% powder	95.8	87.1
	10% dust	1.32	1.2
	5% dust	6.3	5.7
	25% liquid	32.4	29.5
	20% liquid	37.5	34.1
	5% liquid	2817.0	2561.0
Lindane	75% powder	2.0	1.8
	12% liquid	36.0	32.7
DDT-Lindane	15% liquid	21.0	19.1
Chlordane	5% dust	25.0	22.7
	72% liquid	50.0	45.5
2,4-D	50% liquid	78.0	70.9
2,4,5-T	65.3% liquid	36.0	32.7
2,4-D/2,4,5-T	33.5% liquid	132.5	120.5
TOTAL		3373.29	3066.75

Table VIII

QUALITATIVE PESTICIDE SOLUBILITIES IN SELECTED SOLVENTS

	DMF	Acetone	Alcohol	Xylene	Benzene	Methylene Chloride	Carbon Tet	Ether
Chloropropylate								
Aldrin		S	S	S	S	S	S	
Banvel			VS	MS				
Chlordane		S	S	S	S	S	S	
Chloroneb	S	S		S		S		
2,4-D		S	S					S
Dacthal		10%			25%		7%	
2,4-DB		VS	VS		SS			VS
DDT	S	S	S	S	S	S	S	S
Dichlone	SS	SS	SS	S	SS	SS	SS	SS
Dichlorprop		282 gpl		51 gpl	85 gpl			
Dieldrin	MS	MS	MS	MS	MS	MS	MS	MS
Dimethrin	S	S	S	S	S	S	S	S
Diphacin		S						
Endathall		7%	20% (MeOH)		0.01%			0.1%
Endrin		S	SS		S			
Erbon	S	S	S	S	S	S	S	S
Heptachlor			S					
Lindane	S	S	S	S	S			S
MCPP		S	S					S
Methoxychlor	S	S	S	S	S	S	S	S
Mirex				14.3%			7.2%	
PCP			VS					~50%
Butacide	S	S	S	S	S			S
Rotenone		S	S			S		S
Silvex		S	S (MeOH)					
2,4,5-T				S	S			
TCBC		S	S	S	S			
Toxaphene		S	S	S	S			S
Warfarin			MS		SS			

Table IX

CHLORINE PRODUCERS AND ANNOUNCED EXPANSIONS

Chlorine Producers

Name	Capacity	
Alcoa	470	425
Allied Chemical	1650	1500
Diamond Shamrock	2000	1820
Dow Chemical	10100	9180
Du Pont	940	850
Ethyl	640	580
FMC	790	720
Goodrich	300	270
Hooker	1780	1620
Kaiser	535	485
Linden Chlorine	460	420
Mobay	200	180
Monsanto	250	225
Olin	1625	1475
Pennwalt	950	865
PPG	3330	3030
Shell	375	340
Sobin	310	280
Stauffer	980	890
Vulcan	375	340
Wyandotte	1550	1410
Paper Companies	690	625
Other	1180	1070
Total	31480 US Tons/ day	28600 M Tons/ day

Table IX (Cont'd)

CHLORINE PRODUCERS AND ANNOUNCED EXPANSIONS

Announced Chlorine Expansions

Company	Capacity	On Stream
Diamond Shamrock	1200	1974
Hooker	1000	1974
	400	1978
N. L. Industries	220	1974
Georgia Pacific	800	1975
PPG	750	1977
DuPont	1000	1977
Pennwalt	200	1977
Hooker	275	1977
Mobay	200	1975
Weyerhauser	120	1975
Dow Chemical	500	1976
	1000	1977
	500	1978
	1000	1979
Vulcan	600	1977
Olin	1000	1978
Total	10765	

U.S. Tons/day

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Table X

CARBON TETRACHLORIDE PRODUCERS

	Capacity	
	US Tons/year	Metric Tons/year
Allied Chemical	4,000	3,640
Dow Chemical	138,000	125,500
FMC - Allied	150,000	136,400
Stauffer Chemical	210,000	191,000
Vulcan Materials	38,000	34,500
	540,000	491,000

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Table XI

CARBONYL CHLORIDE PRODUCERS

	Capacity	
	US Tons	Metric Tons
Allied Chemical	49,000	45,000
BASF Wyandotte	28,000	25,500
Chemetron	5,000	4,500
DuPont	68,000	61,800
General Electric	30,000	27,300
Mobay	137,500	125,000
Olin	85,000	77,300
Rubicon	63,000	57,300
Union Carbide	55,000	50,000
Upjohn	100,000	91,000
	620,500	564,700

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